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Effect of Swine Manure Extract by Foliar Application and Soil Drenching on Dry Matter and Nutrient Uptake of Cassava

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ABSTRACT

Swine manure extract (SME) is the aqueous liquid obtained by steeping dried swine manure in water for 24 hr and contains plant nutrients. The objective of this study was to compare the effects of nine split applications of SME as foliar fertilizer (FSME) or soil fertilizer (SSME), as well as both soil and foliar fertilizer (FNSSME) and conventional NPK fertilizer (NPK) on the macronutrient and micronutrient uptake of the cassava cultivar Hauybong60. At harvest, 10 mth after planting, the combination of foliar and soil applications of SME favored dry matter and tuber yield improvement and tended to increase the macronutrient and micronutrient uptake by cassava plants. Cassava treated with FSME and NPK produced no significant difference in total dry matter yield, fresh tuber yield or nutrient accumulation in the shoots. The combination of soil and foliar SME application was effective in promoting dry matter, tuber yield and the macronutrient and micronutrient uptake in cassava plants grown on slightly alkaline, loamy soil.

Keywords: swine manure extract, cassava, dry matter yield, nutrient uptake, fertilizer application

INTRODUCTION

Commercial swine production in Thailand is mostly intensive and produces approximately 15 million market pigs per annum (Department of Livestock Development, 2008). Intensive swine production always involves problems with swine manure treatment, farm waste treatment and utilization. Swine manure contains undigested residues and unabsorbed minerals that are present in the feed. Swine manure and effluent consist of various nutrients, including N, P, K, Ca, Mg and several essential micronutrients (Duffera *et al.*, 1999a). King (1981) reported that animal manure would be a valuable nutrient source when applied to soil at rates commensurate with acceptable agronomic practices. Swine waste in the forms of solid, slurry and effluent has been applied to crops with varying yield responses (Burns *et al.*, 1990). Many researchers have reported favorable effects of swine effluent, swine lagoon solids and swine lagoon effluent on nutrient uptake, availability of nutrients and dry matter yield, especially in forage grasses (Adeli and Varco, 2001), bermudagrass (Brink *et al.*, 2003; McLaughlin *et al.*, 2004;), tomatoes (Cushman and Snyder, 2002) and sweet

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corn, sorghum, and field bean (Duffera *et al*., 1999b).

Swine manure extract (SME) is a liquid form of plant nutrient developed by the Suwanvajokkasikit Animal Research and Development Institute, Kasetsart University, Kamphaeng Saen, Nakhon Pathom, Thailand. It is derived from dry swine manure steeped in water for 24 hr and contains full profiles of both macronutrients and micronutrients required by plants. Monthly foliar application of SME increased tuber yield of cassava cultivar Rayong 5 grown on acid sandy soil (Momngam, 2002). The extract has also been shown to increase the yields of rice, vegetables and ornamental plants under practical farm conditions in Thailand (Kanto, U. and Jattupornpong, S., personal communication).

The growing cassava tuber is the major organ for nutrient accumulation, especially K, compared to harvested products of other crops (Howeler, 1991; Putthacharoen *et al*., 1998). Although fertilizer application increased total dry matter (DM) production and tuber yield by about 30%, it nearly doubled the total absorption of N. Indeed, Paula *et al*. (1983) and Howeler (2002) also suggested that total nutrient uptake was highest for N, followed by K, Ca, Mg, P and S, whereas absorption of micronutrients was very low. The roots generally accumulated more K than N, followed by P, Ca, Mg and S, while fallen leaves and stems were high in N and Ca (Howeler and Cadavid, 1983; Paula *et al*., 1983; Putthacharoen *et al*., 1998).

The effects of commercial fertilizer application on cassava yield and nutrient assimilation are well documented (Howeler, 2002; Nguyen *et al*., 2002), but the efficiency of swine manure extract as an alternative source of nutrient for the equivalent N, P or K rates from fertilizer sources has not been studied. It was the objective of the present study to determine the efficacy of swine manure extract as a source of nutrient based on dry matter yield, and to determine the macronutrient and micronutrient uptake at harvesting of the cassava cultivar Hauybong60. A specific objective of this study was to compare the efficacy of the application of conventional chemical fertilizer to that of swine manure extract fertilizer on the yield and the macronutrient and micronutrient uptake of cassava.

MATERIALS AND METHODS

Processed swine manure extract

The concentrated swine manure extract (CSME) was produced by steeping dry swine manure in water at a ratio of manure to water of 1:10 (w/v) for 24 hr (the "tea-bag" method) and filtering out the solids**.** The chemical properties of concentrated swine manure extract and the pH were determined by electrode potentiometer (Cyberscan pH 1000, Eutech Instruments, Holland) and electrical conductivity was determined using an electrical conductivity meter (ATI Orion model 162, Thermo Electron Corporation, USA). The concentrations of total N, K and P were analyzed by the micro-Kjeldahl procedure (Tecator 1026 Distilling Unit, Foss, Denmark) (Bremner and Tabatabai, 1972), using an emission flame photometer (Shimadzu AA-6300, Shimadzu Corporation, Japan) and colorimetry (Shimadzu UV-1700, Pharmaspec, Shimadzu Corporation, Japan) with a vanadomolybdic reagent, respectively. The determinations of Ca, Mg, Fe, Cu, Mn and Zn in concentrated swine manure extract were carried out by wet digestion of the sample with a mixed digestive acid (HNO_3/$HClO_4$), and mineral concentrations were determined by atomic absorption spectrometry (Shimadzu AA-6300, Shimadzu Corporation, Japan). The properties and nutrient composition of the concentrated swine manure extract are shown in Table 1. The extract was further diluted with water at a ratio of the extract to water of 1:10 by weight to obtain swine manure extract (SME) that was then used in all experiments throughout the study.

Table 1 Chemical properties and average nutrient content of the concentrated swine manure extract (CSME).

Chemical properties	Dry swine manure to water (1:10) (CSME)
pH	6.8
EC ($dS.m^{-1}$)	9.85
N ($mg.g^{-1}$)	1
P ($mg.g^{-1}$)	0.25
K ($mg.g^{-1}$)	1.5
Ca ($mg.kg^{-1}$)	115.37
Mg ($mg.kg^{-1}$)	119.73
S	Trace
Fe ($mg.kg^{-1}$)	1.36
Cu ($mg.kg^{-1}$)	14.06
Mn ($mg.kg^{-1}$)	1.73
Zn ($mg.kg^{-1}$)	0.43
Na ($mg.kg^{-1}$)	303

Location, planting material and experimental design

The on-farm field experiment was conducted in loamy soil (sand 31.6%, silt 45.82%, clay 22.58%), with a pH of 7.6–7.9 which was classified as a Chatturat soil series (fine, mixed, active isohyperthermic Typic Haplustalfs; Land Development Department, 2003) in U-Thong district, Suphanburi province, Thailand (latitude 14°24′N, longitude 99°51′E). Sixteen experimental plots, each 6 × 16 m, were established. Before planting and after harvesting the plants, soil samples were collected from a depth of 15 cm from the surface of each plot. The samples were air-dried, ground and passed through a 2 mm stainless steel sieve. Particle size distribution was determined by a pipette method after pretreatment to remove soluble salts, organic matter and carbonates (Gee and Bauder, 1986). Soil organic carbon was determined according to Walkley and Black (1934). Soil pH was measured in water at a soil-to-water ratio of 1:1. Available P and K in the soil were determined by colorimetry in Bray-II extracts (Bray and Kurtz, 1945) and atomic absorption spectrometry, respectively. Soil exchangeable Ca^{2+} and Mg^{2+} were extracted by ammonium acetate at a pH of 7.0. Exchangeable Fe, Cu, Mn and Zn were extracted with diethylenetriaminepentaacetic acid (DTPA) solution (Jones, 2001).

Cassava stakes aged 10 mth and 15–20 cm long were planted at 1 × 1 m intervals (96 $plants.plot^{-1}$) and were randomly subjected for 10 mth to one of four fertilizer treatments—namely, 1) conventional NPK fertiliser (NPK), formula 21-10-10 at 250 $kg.ha^{-1}$, with 52.50 kg N, 25 kg P_2O_5 (10.94 kg P), and 25 kg K_2O (20.81 kg K) per hectare, respectively; 2) nine foliar applications of swine manure extract (FSME) with 2.50, 0.5 and 3.96 $kg.ha^{-1}$ of N, P and K, respectively, plus secondary elements and micronutrients contained in SME; 3) nine soil applications of SME (SSME) with 17.81, 3.56 and 26.69 $kg.ha^{-1}$ of N, P and K, respectively, plus secondary elements and micronutrients contained in SME; and 4) nine foliar and soil applications of SME (FNSSME) with 20.25, 4.06 and 30.38 $kg.ha^{-1}$ of N, P and K, respectively, plus secondary elements and micronutrients contained in SME (Table 1). Conventional NPK fertilizer (NPK) was applied on day 45 after planting and SME as foliar (FSME and FNSSME) or soil fertilizer (SSME and FNSSME) was applied every 30 d from day 45 until day 245 after planting. The application rate of SSME was 2.5 $L.plant^{-1}.month^{-1}$. The total amount of SME applied for the FSME, SSME and FNSSME treatments throughout the study were 24,869, 178,000, and 202,878 $L.ha^{-1}$, respectively. The four fertilizer treatments were arranged in a randomized complete block design with four replications.

Data collection

Dry matter yield was determined by drying the leaves, stems and tubers of the 10-month old plants in an oven at 65–70°C until constant weights were obtained. The determinations of Ca, Mg, Fe, Cu, Mn and Zn in the dry matter of every plant component were carried out by wet digestion of the sample with a mixed digestive acid ($HNO_3/HClO_4$) and mineral concentrations were determined by atomic absorption spectrometry. The concentrations of K and P were analyzed using the emission flame photometer and colorimetry with a vanadomolybdic reagent, respectively. The separated samples were determined for total N by the micro-Kjeldahl procedure (Bremner and Tabatabai, 1972). The concentration of S was analyzed by turbidimetry with a barium chloride/PVA mixture. Nutrient uptake was calculated as the product of the nutrient concentration and DM yield for each plot at harvest.

Statistical analysis

The mean values of nutrient uptake and DM yields from each treatment were analyzed with analysis of variance and the differences among treatment means were determined by Duncan's multiple range test (SAS Institute, 2003). Means that differed at $P \leq 0.05$ were considered to be significant.

RESULTS AND DISCUSSION

Chemical properties and nutrient profile in concentrated swine manure extract

The concentrated swine manure extract was slightly alkaline, and had high electrical conductivity and Na content, but the electrical conductivity (EC) and Na content of the SME diluted to 1:10 used in all applications was reduced. SME contained the full profile of nutrients required by the plants, especially micronutrients (Table 1). The average total concentrations of N, P and K in concentrated SME were 0.1, 0.025 and 0.15 $mg.g^{-1}$, respectively. The form of N was not determined in the study. However, Adeli and Varco (2001) reported that swine effluent N existed primarily as NH_4/NH_3-N (84%) with minimal NO_3^- - N content (2.2%). This information was in agreement with Cushman and Snyder (2002), who reported that about 70–90% of the N content of the effluent from anaerobic swine lagoons was in the form of NH_4-N.

Soil analysis

Soil samples from every treatment had a pH that was slightly alkaline and electrical conductivity of the soil was classified as low. Soil samples from every treatment contained medium organic matter, medium available P, and high-exchangeable K (Department of Agriculture, 2005). Exchangeable Ca, Mg, and extractable Mn in the soil samples of every treatment were classified as high, while extractable Cu was low to medium. The level of extractable Fe and Zn in this soil was low (Department of Agriculture, 2005).

Dry matter and yield

There were no significant differences in the fresh weight and dry matter yield of each plant component, nor in the total weight of cassava among the treatments (Table 2). However, foliar application (FSME), soil application (SSME) and both foliar and soil applications (FNSSME) of SME tended to enhance greater average weights of dry root, fresh root, leaf, stem and the whole plant and dry matter yields than those of NPK treated plants. It was noted that FNSSME treatments improved the production of dry roots, stem weight, leaf weight and total dry matter yield by 41.99, 38.63, 8.65 and 38.52%, respectively, compared to those results from NPK treatments. The results of this study clearly showed that under field conditions, foliar application of SME (FSME) produced a comparable root yield to that promoted by conventional fertilizer application. Soil application of SME (SSME) or SSME in combination with FSME tended to increase tuber fresh and dry weight by 28.87 and 41.99%, respectively, compared to those in a chemical fertilizer treatment. SME contains not only the macronutrients, but also essential micronutrients required by the plant. The monthly split application of SME, either via soil or foliar application, or via both soil and foliar applications throughout the growing season, provided an appropriate distribution of nutrients for cassava and resulted in favorable growth and yield production from the plants. The NH_4-N, soluble P, K and several micronutrients in SME could be directly taken up by plants. The combination of foliar and soil applications of SME increased total dry matter and tuber yield by 38.52 and 28.87%, respectively, compared to those receiving chemical fertilizer application. Conventional NPK fertilizer failed to promote optimal dry matter yield because there were neither secondary elements nor microelements. The application of the fertilizer only once at 45 d after planting may have not prolonged the essential nutrient supply for the duration of the 10 mth growth period. The high solubility of fertilizer plant nutrients may have caused their loss by rain or irrigation leaching (Fageria, 2009). Figure 1 shows that there was high rainfall in July and the soil matric potential at 35 cm soil depth was -40 to -30 kPa. Brink *et al*. (2003) reported that the application of swine effluent produced a similar yield of Russell hybrid bermudagrass to that promoted by inorganic N, which was consistent with the results with tomatoes of Cushman and Snyder (2002) who demonstrated that plants receiving swine effluent could produce marketable yields and a relative number of marketable fruits equal to that of plants that received fertilizer from an inorganic pre-plant or soluble source. All of these studies have proved that sufficient supply and split applications of swine effluent or swine manure extract improve dry or fresh matter yield and could partially replace or totally substitute conventional, chemical fertilizer in some soil types.

Table 2 Dry matter and fresh yield of cassava plant components grown with conventional fertilizer and swine manure extract application.

Plant	Yield ($Mg.ha^{-1}$)	
Component	Fresh	Dry
Root		
NPK	59.93	22.31
FSME	61.13	21.81
SSME	72.47	27.27
FNSSME	77.23	31.68
Pr > F	0.1903	0.1668
Stem		
NPK	31.53	9.99
FSME	32.90	9.79
SSME	31.03	9.88
FNSSME	38.30	13.85
Pr > F	0.6089	0.2313
Leaf		
NPK	9.20	2.66
FSME	9.40	2.32
SSME	11.23	3.05
FNSSME	10.80	2.89
Pr > F	0.3114	0.1892
Total		
NPK	100.67	34.96
FSME	103.43	33.92
SSME	114.73	40.21
FNSSME	126.33	48.43
Pr > F	0.2435	0.1093

NPK = Conventional fertilizer; FSME = Foliar application of swine manure extract; SSME = Soil application of swine manure extract; FNSSME = Foliar and soil application of swine manure extract.

Macronutrient uptake of cassava plant

The macronutrient uptake of cassava growing under different regimes of SME applications up to the time of harvest in comparison with that of plants receiving conventional NPK fertilizer (NPK) is shown in Table 3. There were no significant differences in macronutrient uptake in the fresh roots, stems, leaves and total plants of cassava growing under different fertilizer treatments, except for Ca and S. The total amounts

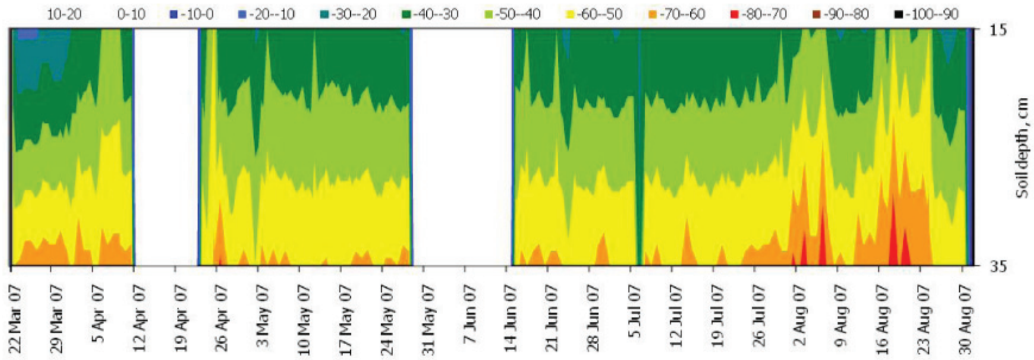

Figure 1 Soil matric potential in the treatment plots at 15 to 35 cm soil depth during the study.

Table 3 Macronutrient uptake of cassava at harvest time.

Treatment	Nutrient content (kg.ha^{-1})					
	N	P	K	Ca	Mg	S
Root						
NPK	121.92	18.26	181.19	42.16	26.23	60.65
FSME	120.13	18.46	210.05	38.61	31.42	62.49
SSME	114.38	21.64	257.49	45.37	35.55	59.14
FNSSME	148.22	26.66	257.59	54.40	39.48	67.99
Pr > F	0.6443	0.3259	0.7969	0.2885	0.5580	0.9400
Stem						
NPK	63.64	10.85	90.21	100.87	17.02	21.09
FSME	72.42	10.36	107.52	89.10	31.51	27.99
SSME	51.92	10.26	77.14	103.10	34.28	36.16
FNSSME	84.62	15.49	102.89	141.13	40.43	62.14
Pr > F	0.3717	0.1416	0.7949	0.0522	0.1999	0.0542
Leaf						
NPK	110.75	6.27	29.41	79.74 a†	10.83	12.68 a
FSME	101.38	5.59	28.67	56.67 b	10.33	9.45 b
SSME	132.09	7.77	28.10	89.31 a	15.31	13.53 a
FNSSME	130.85	6.71	24.27	85.48 a	11.04	12.82 a
Pr > F	0.0815	0.1385	0.5632	0.0126	0.0839	0.0059
Total						
NPK	296.31	35.38	300.82	222.78 ab†	54.08	94.41
FSME	297.93	34.41	346.24	184.38 b	73.27	99.93
SSME	298.39	39.67	362.73	237.79 ab	85.15	108.83
FNSSME	363.69	48.86	384.74	281.01 a	90.94	142.94
Pr > F	0.3307	0.2000	0.9285	0.0246	0.3138	0.2760

NPK = Conventional fertilizer; FSME = Foliar application of swine manure extract; SSME = Soil application of swine manure extract; FNSSME = Foliar and soil application of swine manure extract.

† = Different letters in a column within each plant component grouping indicate significantly different means at $P < 0.05$ according to Duncan's multiple range test (n = 4).

of macronutrient uptake ($kg.ha^{-1}$) of cassava under different fertilizer treatments were in the following ranges: N, 296.31–363.69; P, 34.41–48.86; K, 300.82–384.74; Ca, 184.38–281.01; Mg, 54.08–90.94 and S, 94.41–142.94 (Table 3). The cassava treated with FNSSME tended to have higher total weight and accumulated relatively higher total N, P, K, Ca, Mg and S compared to the other treatments. Cassava under FNSSME received both soil and foliar applications of SME, which provided not only greater amounts of N, P and K compared to cassava under other SME fertilizer applications, but also received the greatest amounts of other macronutrients (Ca, Mg and S). The more macronutrients supplied to the plants, the more biomass and dry matter produced as a direct consequence of greater nutrient uptake from the soil. Cassava usually removes higher K than any other crops such as sweet potatoes, maize, rice and wheat (Howeler, 1991; Putthacharoen *et al*., 1998). The amount of nutrient uptake by the plant or that removed by the harvested root are highly dependent on growth rate and root yield, which in turn depend on climate, soil fertility and plant varieties (Howeler, 2002). There was variability in the nutrient content of the roots and in the whole plant depending on plant yield (Fageria, 2009). However, Shinano *et al*. (1994) reported that the amount of N accumulated in cereal and legume species showed a highly positive correlation with the total dry matter produced at harvest. Fageria (2009) concluded that the quantity of P, Ca and Mg removed by a crop depended on the yield level, dry weight of shoots and grain yield. FNSSME significantly enhanced uptake of S released from soluble protein in SME (Sinclair, 1993). The maximum and minimum contents of S uptake were associated with the yields of barley, buckwheat, corn, oats, rice, wheat, sorghum, peanuts and flax (Hanson, 1990). Cassava plants producing high yields always have higher variation in the nutrient content in the roots and the whole plant than those with lower yields (Howeler and Cadavid, 1983; Howeler, 2002). The results of the present study have revealed significant correlations between dry matter yield of cassava and the plant uptake of: N ($r = 0.7371$, $P < 0.01$); P ($r = 0.9081$, $P < 0.01$); Ca ($r = 0.8904$, $P < 0.01$); Mg ($r = 0.8290$, $P < 0.01$); and S ($r = 0.8963$, $P < 0.01$). Adeli and Vacro (2001) also showed that application of swine effluent significantly increased N concentration in forage grasses, with both N and P tissue concentration having an influence on the dry matter yield of the forage grasses. McLaughlin *et al*. (2004) reported that there was a significant correlation between swine effluent spraying in the field across all three years of the trial and DM yield and N, P and K uptakes for common bermudagrass ($r = 0.99$, $P = 0.0001$).

Micronutrient uptake of cassava plant

Micronutrient uptake of cassava growing under different regimes of SME applications up to harvest time when compared to that of plants receiving conventional NPK fertilizer (NPK) is shown in Table 4. There were no significant differences in the uptake of most micronutrients in the fresh roots, stems, leaves and total plants of cassava growing under different fertilizer treatments, except for Fe. The distribution of Fe in cassava plants at harvest varied among treatments. The plants treated with FNSSME tended to accumulate Fe more in the roots and stems than in the leaves, indicating the distribution of the element to the storage organs at maturity. The ranges in the amounts ($kg.ha^{-1}$) of total micronutrient uptake of cassava in different fertilizer treatments were: Fe, 4.12–7.11; Cu, 0.12–0.21; Mn, 0.45–0.93; and Zn, 0.33–0.55. The cassava treated with FNSSME exhibited the highest total micronutrient uptake, due to also having the highest dry matter yield, although the differences among other treatments were not significant. Cassava under FNSSME received both soil and foliar applications of SME which provided the highest amount of micronutrients

(Fe, Cu, Mn and Zn) to supplement the limited amounts of Fe, Cu, and Zn in the soil. Although the level of extractable Fe in the soil was low, Fe uptake by cassava plant in FNSSME tended to be the highest. This indicated that FNSSME could supplement for the Fe nutrient required by the plant. The more micronutrients supplied to the plants, the more biomass and dry matter produced; this was a consequence of greater nutrient uptake from the soil. The results of this study also found a significant correlation between dry matter yield and Fe uptake ($r = 0.7923$, $P < 0.01$) and Cu uptake ($r = 0.8199$, $P < 0.01$). The data of this study were in agreement with an earlier report by McLaughlin *et al*. (2004) that showed spraying swine effluent in the field favored Cu uptake in bermudagrass in three growing seasons and resulted in increased DM yields. Lipoth and Schoenau (2007) demonstrated that long-term repeated application of liquid swine effluent sometimes resulted in increased plant availability of Cu and Zn, as reflected in increased concentrations of the plant-available metals observed in both the soil and plant tissue. However, all mineral absorption by plants depends on plant age and the nutrient concentration in the soils (Fageria, 2009; Howeler, 2002).

Table 4 Micronutrient uptake of cassava at harvest time.

Treatment	Nutrient content ($kg.ha^{-1}$)			
	Fe	Cu	Mn	Zn
Root				
NPK	0.14	0.03	0.04	0.20
FSME	0.24	0.01	0.04	0.15
SSME	0.20	0.03	0.06	0.25
FNSSME	0.31	0.05	0.09	0.28
Pr > F	0.1380	0.0868	0.5950	0.1939
Stem				
NPK	3.81	0.08	0.25	0.13
FSME	3.59	0.09	0.21	0.11
SSME	3.70	0.10	0.22	0.14
FNSSME	6.63	0.14	0.47	0.17
Pr > F	0.2526	0.2180	0.4936	0.4350
Leaf				
NPK	0.42	0.02	0.26	0.10
FSME	0.29	0.02	0.20	0.07
SSME	0.24	0.02	0.30	0.11
FNSSME	0.17	0.02	0.37	0.10
Pr > F	0.0648	0.2255	0.7669	0.3230
Total				
NPK	4.37	0.12	0.55	0.42
FSME	4.12	0.12	0.45	0.33
SSME	4.13	0.15	0.58	0.49
FNSSME	7.11	0.21	0.93	0.55
Pr > F	0.2531	0.1501	0.6220	0.2408

NPK = Conventional fertilizer; FSME = Foliar application of swine manure extract; SSME = Soil application of swine manure extract; FNSSME = Foliar and soil application of swine manure extract.

The fertilizer treatments were carried out in alkaline, loamy soil containing medium levels of organic matter and available P, high-exchangeable K, Ca, Mg and extractable Mn, and low levels of extractable Fe, Mn, and Zn. It was found that foliar and soil applications of SME significantly favored Ca accumulation by the whole plant. Soil application (SSME) or the combination of foliar and soil applications of SME (FNSSME) showed a tendency for an increase in Mg, S, Fe, Cu, Mn and Zn concentrations in the total dry tissue of cassava, which was related to the nutrient provided by this fertilizer (Tables 3 and 4). The results of the study revealed that total nutrient absorption was highest for K, followed by N, Ca, S, Mg, P, Fe, Mn, Zn and Cu for all treatments. However, the results of this study were inconsistent with Paula *et al*. (1983) who reported that total nutrient uptake was highest for N, followed by K, Ca, Mg, P and S, but absorption of micronutrients was extremely low. Foliar application of SME (FSME) provided the lowest dry matter yield of cassava. On the other hand, foliar and soil applications of swine manure extract (FNSSME) increased the total dry matter production and tuber yield by 38.52 and 28.87%, respectively, compared to the yields from chemical fertilizer application. The authors of the present study believe that swine manure extract may contain a plant growth regulator—namely, 5-aminolevulinic acid—that has a role in enhancing the vegetative part and yield of cassava (Sasikala et al., 1994). Therefore, further study should determine the content of plant hormones/plant growth regulators contained in the SME used in the study to support understanding of the effectiveness of SME as a plant growth promoter in addition to its role as a source of plant nutrient.

CONCLUSION

Swine manure extract applied monthly was as effective as conventional NPK fertilizer in promoting dry matter and tuber yield of cassava, especially in soils containing limited available micronutrients. The combination of foliar and soil applications of SME favored dry matter and tuber yield improvement and tended to increase macronutrient and micronutrient uptake by cassava plants. Foliar and soil applications of SME allowed cassava to maintain an appropriate nutrient status, but a foliar application of only swine manure extract did not elevate the level of macro and micronutrients in the whole plant tissue of cassava to the same extent as in the other two treatments; however, it was comparable to chemical fertilizer in terms of tuber yield production. The results of the study showed that, in this loamy soil type, the continuous split of a monthly swine manure extract program could partially replace the traditional or chemical fertilizer application for nutrient management of cassava production. The effects of SME should be tested with other soil types in areas where cassava is planted. Modification of the application procedure is exceptionally cheap, and the use of liquids to minimize labor costs needs further study.

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